Journal of Chemical and Natural Resources Engineering, Special Edition:40-53

USED COOKING OIL AS A SOURCE FOR BIODIESEL BLEND

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ABSTRACT

With the depleted world petroleum reserves and increase demand for oil as a fuel, it has become imperative to investigate the possibility of using non-fossil fuel as an alternative fuel for diesel engine. Therefore, this paper describes the experimental investigation on possibility of producing biodiesel from used cooking oil and their properties, characteristics and performance as a blended biodiesel for diesel engine at constant speed. Properties analysis of biodiesel from used cooking oil in accordance to the ASTM D6751 specification showed that it fulfilled the requirements of a biodiesel fuel specification. Comparison also conducted between the ordinary diesel as a standard fuel and several set of blended biodiesel range from 1% to 5% volume of biodiesel. The properties of blended biodiesel were not much different to the properties of conventional diesel fuel except the density and specific gravity. The density of diesel is 0.8358 gm/cc and the biodiesel is 0.8723 gm/cc. For blended biodiesel, it's slightly increased from 0.8363 gm/cc for 1% to 0.8385 gm/cc for 5%. The results from Detroit Deisel Engine performance test showed that the blending fuel sample produced almost the same performance characteristics as compared to conventional diesel. As a result, blended biodiesel with used cooking oil is suitable to be used up to 5% as a fuel for diesel engine at constant speed and gives the same engine performances as conventional diesel fuel

1.0 INTRODUCTION

With the exhaustion or near exhaustion of world petroleum reserves, it has become imperative to investigate the consequences of using non-petroleum fuel in automobiles and power plants or stationary engines [1] In the light of these events; it is worthwhile reconsidering the forms of alternative fuels. The performance characteristics and emissions characteristics of these fuels should be studied and tested.

Some states in the US are legislating similar requirements. There are a growing number of US suppliers and sales are rising fast, though biodiesel is more expensive than ordinary diesel in the US [2]. The Brazilian Biodiesel Program makes the initial use of biodiesel, in the proportion of 2%, compulsory; representing an annual demand of 800 million liters of the Biofuel[3]. Germany has thousands of filling stations supplying biodiesel, and it's cheaper there than ordinary diesel fuel. All fossil diesel fuel sold in France contains between 2% and 5% biodiesel. New EU laws will soon require this Europe-wide. In the UK, many only maintain their engine warranties for use with maximum 5% biodiesel blended in with 95% conventional diesel; although this position is generally considered to be overly cautious [4].

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However, oils of vegetable and animal origin, unlike fossil fuels, have potential to be produced not only on a sustainable basis but also could be greenhouse gas neutral, or at the very least, emit substantially less greenhouse gases per unit energy than any of the fossil fuels.

Therefore, this study was conducted to determine the characteristic of blended biodiesel from used cooking oil and diesel fuel that suitable and gives the optimum fuel performance.

2.0 METHODOLOGY

Laboratory works had divided into four parts, which are sample preparation, blending sample preparation, properties determination and performance characteristic of diesel engine.

2.1 Sample Preparation

i) Test for Water Content

First, content of water in used cooking oil must be tested with the following procedures:

(a) Half liter of oil sample was heated in 1 liter beaker and the temperature monitored with a thermometer.

(b) If there's water, it will start to "snap, crackle and pop" by 50 °C (120 °F). S the sample must be dewatered by:

i. Heated to 60 °C (140°F) and maintained the temperature for 15 minutes
ii. Then the oil was poured into the settling tank and let it settled for at leas 24 hours.

(c) If it's still not crackling by 60 °C (140 °F), there's no need for dewatering an proceed to next step.

ii) Lye Requirement Determination

Refined fats and oils have a free fatty acid (FFA) content of less than 0.1%. FFA i formed during cooking, and they interfere with the transesterification process for makin biodiesel. For used cooking oil, there is a need to use more lye catalyst (sodium hydroxide o potassium hydroxide) to neutralize the FFA. The extra lye turns the FFA into soap whic drops out of the reaction along with the glycerine by-product. Procedures to determine th additional lye needed to neutralize the FFA are as follows:-

(a) 1 gm of lye (NaOH) was dissolved in 1 liter of distilled water (0.1 % w/v ly solution, weight to volume).

(b) In a smaller beaker, 1 ml of the oil was dissolved in 10 ml of pure isopropy alcohol and warmed gently by standing it in some hot water, stirred until al the oil dissolves in the alcohol and turns clear.

(c) 2 drops of phenolphthalein was added to the solution.
(d) 0.1% NaOH solution was added (drop by drop) using a graduated syringe or a pipette to the oil-alcohol-phenolphthalein mixture and stirred. It might turn a bit cloudy, keep stirring. Keep on carefully adding the NaOH solution until the mixture starts to turn pink (magenta) and stays that way for 15 seconds.
(e) The number of milliliters of 0.1% NaOH solution used was recorded and added with 3.5 (the basic amount of NaOH needed for fresh oil). This is the number of grams of NaOH needed per liter of oil titrated.

iii) Methoxide Preparation

Sodium hydroxide catalyst is dissolved in the alcohol using standard mixer or stirrer. The mixture gets hot from the reaction, forming sodium methoxide. The procedures for methoxide preparation are as follows:-

(a) 200 ml of methanol was measured and quickly poured into the half-liter bottle sample via the funnel. Methanol also absorbs water from the atmosphere so does it quickly and the lid of the methanol container was replaced tightly.
(b) 3.5 grams of lye (NaOH) was measured and additional grams of lye to neutralize the FFA in the waste oil sample were added.
(c) The lye was carefully added to the methanol container via the second funnel. The lid of the methanol container was replaced again tightly.
(d) The container was stirred a few times until all lye dissolved
(e) The next process begun as soon as the liquid is clear with no undissolved particles in it.

iv) Transesterification Process

Transesterification is the process that combines vegetable oil or animal fats with alcohol/catalyst mixed to form methyl ester or biodiesel. After settling, darker-coloured glycerine by-product will be collected in a distinct layer at the bottom of the bottle, with a clear line of separation from the pale liquid above, which is the biodiesel, as shown in Figure 1. The biodiesel varies in colour according to the oil used but usually it's pale and yellowish Procedures for this process is as follow:-

(a) 1 liter of used cooking oil was measured and poured it into 2.5 liter container.
(b) The oil was pre-heated to 55 deg C (130 °F).
(c) The prepared methoxide solution was carefully poured into the oil.
(d) The container lid was tightly secured and the stirrer/mixer was switched on with low speed. The mixer was blended for at least 20 minutes.
(e) The mixer was allowed to settle for 12-24 hours.
(f) The top layer of biodiesel was carefully decanted into a clean jar or PET bottle, precaution of not to get any of the glycerine layer mixed up with the biodiesel was taken. If you do, re-settle and try again.

Figure 1 Biodiesel after settling for 24 hours

Figure 2 First wash with milky water at bottom

Figure 3: Third wash with clear water at the bottom

v) Washing

Once separated from the glycerine, the produced biodiesel is purified by washin gently with warm water to remove residual catalyst or soaps, dried, and sent to storage. Th first wash water turns white, like milk, as shown in Figure 2. Washing is completed when th

water is clear after settling as shown in Figure 3, with a pH of 7, usually after the third or fourth wash. Procedures for washing are as follows:-

(a) The biodiesel from the settling container was transferred to new container, leaving all the glycerine by-product behind.
(b) Half-liter of fresh water was added into the biodiesel container and mixed using a stirrer to the point of appearing homogenous for about 5 minutes.
(c) The mixture was allowed to settle for 1 hour.
(d) The top layer of fuel was siphon off and steps (b) to (d) were repeated for after two cycles.
(e) The fuel was heated to 120 deg F (48 deg C) to dry and allowed it to cool.

2.2 Blending Sample Preparation

The blended biodiesel was prepared with the composition as shown in Table 1. Following steps are the detail procedures to blend the produced biodiesel with conventional diesel:

(a) For 1 liter of blended biodiesel, 990 ml of conventional diesel which is 99% of total volume was measured and poured to 1.5 liter bottle.
(b) 10 ml of prepared biodiesel which is 1% of total volume was measured and poured to same bottle containing conventional diesel.
(c) The lid was screwed tightly and this bottle was shaking violently for 1 to 2 minutes until the mixture is homogeneous.
(d) Steps (a) to (c) were repeated using other composition of biodiesel blended with conventional diesel as shown in Table 1.

Table 1 Composition of blending samples

Sample	Conventional Diesel Content (% volume)	Biodiesel Content (% volume)
B1	99	1
B2	98	2
B3	97	3
B4	96	4
B5	95	5

2.3 Fuel Properties Determination

i) Density Determination

This test method specifies a procedure for the laboratory determination using a glass hydrometer, of the density and API gravity of the fuel sample. The values of API gravity for each blended sample were determined as ASTM D1298-85 with the following procedures:

(a) Cylinder containing the sample was placed in a vertical position in a free fron air current location.

(b) The appropriate hydrometer was lowered into the liquid and released. Car was taken to avoid wetting the stem above the level at which it floats freely.

(c) The meniscus shape was observed when the hydrometer is passed below th point of equilibrium by one or two millimeters and allowed to return t equilibrium. If the meniscus changes, the hydrometer stem should be cleaned.

(d) This procedure was repeated until the meniscus shape remains constant whe the above test is carried out.

(e) The sample temperature was measured to the nearest 0.1°C using th appropriate thermometer.

(f) The hydrometer was depressed about two scale divisions into the liquid, an then releases it. The remainder of the stem of the hydrometer, which is abov the level of the liquid, must be kept dry, since unnecessary liquid on the st affect the reading obtained.

(g) The reading of hydrometer scale was taken to the nearest one fifth of a scal diversion when the hydrometer has come to rest, floating freely away from th walls of the cylinder.

(h) With the hydrometer reading data, the corrected hydrometer reading to densit was determined using Table 3 of ASTM Standard for Petroleum Measuremen Table.

ii) Pour Point Determination

The pour point of each blended sample was determined as ASTM D97-87 with th following procedures:

(a) 50ml of oil was poured into the test jar.

(b) The test jar was closed tightly by cork carrying the thermomete approximately 3mm below the surface of the oil.

(c) The disk was placed at the bottom of the jacket. The ring gasket was pla around the test jar, 25mm from the bottom. The test jar was inserted into th jacket.

(d) The test jar was carefully removed from the jacket and tilted it just enough t ascertain whether there is a movement of the oil in the test jar. The complet operation of removal and replacement shall require not more than 3 sec. A soon as the oil in the test jar does not flow when the jar is tilted, the tests ja was hold in a horizontal position for exactly 5 sec.

(e) The test jar was replaced immediately in the jacket if the oil shows an movement under these conditions and a test for flow was repeated at the nex temperature 1°C lower.

(f) Continue the test in this manner until a point is reach where the test jar show no movement when the test jar is held in a horizontal position for exactly sec. Record the observed reading of the test thermometer as observed pou point of this sample.

iii) Flash Point Determination

The flash point of each blended sample was determined as ASTM D3828-87 with the following procedures:

(a) Setaflash Closed Tester was switched on and the temperature control knob was turned slowly until the indicator light is on.
(b) The temperature of the sample cup was recorded when it stabilize which is the indicator light is slowly cycles on and off.
(c) 2ml specimen of the sample is charged with the syringe and transferred to sample cup through filling orifice.
(d) Gas control valve was opened and lighted the pilot and test flame. The test flame was adjusted with the pinch valve to the size of the 4mm gauge.
(e) The timer is set by rotating its knob clockwise to its maximum value.
(f) The test flame was tested after the time signal indicates the specimen is at test temperature. This step is done by slowly and uniformly opening the shutter and closing it completely over a period of approximately 2.5 seconds.
(g) The test temperature and results were recorded as 'flash' or 'no flash'
(h) The procedures were repeated at additional 1°C from the test temperature before using the sample fuel sample until the flash is observed as step (f). When the flash was indicated as in step (f), the observed temperature was record as flash point for the sample.

2.4 Performance Characteristics Test of Diesel Engine

i) Performance Test

The objective of this study is to investigate the performance and behavior of the engine under constant speed conditions. This experiment was run using Detroit Diesel Engine. For each experiment, the engine speed is defined at 1000 and 2000 r.p.m. At each particular speed, after the engine had reached a stable condition, readings of speed, load and time to consume 50ml of fuel was recorded. The procedures for this test are defined as follows:

(a) 5 liter of fuel sample was measured and poured into the engine fuel tank.
(b) Engine is turned on and the engine speed was slowly increased to 600-900 rpm. The dynamometer was set at zero value.
(c) The engine was allowed to stabilize at this condition for 5 minutes.
(d) The load and fuel supply were adjusted to get an engine speed of 1000 rpm.
(e) The brake load was increased to give reading of 2kg on the dynamometer readout while making sure the engine speed stays at 1000 rpm by adjusting the fuel sample.
(f) The engine was stabilized and the fuel supply valve was closed to determine the timing of 50ml fuel to be consumed by the engine. The reading of timing was recorded.

(g) The fuel supply valve was reopened, the timing had been reset and steps (e and (f) were repeated with an increased of 2kg brake load and using an engin speed at 2000 rpm.

(h) The whole procedures were repeated with other blended fuel sample.

(i) Data for speed, brake load and fuel consumption time had been analyzed t determine brake power, brake mean effective pressure, specific fu consumption and brake thermal efficiency using equation given below.

ii) Performance Criterion

The performance criterion for this diesel engine is determined by calculated the Brak Power, Specific Fuel Consumption and Brake Thermal Efficiency of the engine [5,6,7].

(a) Brake Power Calculation

Brake Power (BP) is the net power produced by an engine at the crankshaft and c be obtained using the following equation:

$$BP = \frac{T \times N \times 2\pi}{60\,000} \quad (\text{kWatts}) \qquad (1)$$

$$T = \text{Torque} = W \times R \qquad (2)$$

W = Brake Load (N)
= load(kg)x 9.81 m/s^2

R = Torque Arm Length (0.575m)
N = Engine Speed (r.p.m.)

$$BP = \frac{W \times 0.575 \times N \times 2\pi}{60\,000} \quad (\text{kW}) \qquad (3)$$

(b) Brake Mean Effective Pressure Calculation

Brake mean effective pressure (Pb) is the average pressure acting on the piston th produces the same amount of work, as defined by Eq. (4). It is useful as a parameter t compare the performance of dissimilar engines.

$$Pb = \frac{(BP) \times 60}{LAnN} \quad (\text{kPa}) \qquad (4)$$

L = Stroke Length (0.127 m)
A = Piston Cross Section Area (m^2)
n = number of cylinder.

(c) Specific Fuel Consumption Calculation

Specific fuel consumption (Sfc) is the amount of fuel consumed by the engine to produce a unit amount of work or as a rate of fuel consumed to produce a kilowatt of power. It is the parameter to compare fuel economy among dissimilar engines. The value is defined by:

$$Sfc = \frac{3600 \times m_f}{BP} \text{ (kg/kW.hr)} \quad (5)$$

m_f = Fuel mass flow rate

$$= Vf \times \rho_f \text{ (kg/s)} \quad (6)$$

ρ_f = Fuel density (kg/m^3)

Vf = Volumetric fuel flow rate

$$= \frac{50 \times 10^{-6}}{t} \text{ } (m^3/s) \quad (7)$$

t = Time for 50 ml fuel consumption (seconds)

(d) Brake Thermal Efficiency Calculation

Brake thermal efficiency is the ratio of net power produced by the engine to the rate of heat supplied from combustion of fuel. It shows the percentage of heat energy that is converted to work as defined by eq. (8).

$$\eta b = \frac{BP \times 100}{m_f \, LCV} \text{ (\%)} \quad (8)$$

LCV = heat value/ Heat of Combustion

3.0 RESULTS AND DISCUSSIONS

3.1 Properties of Biodiesel and Blended Biodiesel

The results show that methyl ester of acceptable quality can be produced from used cooking oil by a simple method of esterification. In spite of the varying quality of the oil, the properties of most sample of biodiesel from used cooking oil were largely within specifications. The results of produced biodiesel properties from used cooking oil were shown in Table 2. Average density was 0.8723 g/cm^3, with little variation and well within specification limits. Pour point was 8 °C, which is below the maximum value of specification requirements. The flash point gave the average value of 168 °C, generally above the specification. It is clear that the biodiesel produced from used cooking oil can be accepted as a biodiesel blended fuel.

Table 2 The properties of 100% biodiesel from waste cooking oil (B100)

Sample	Biodiesel sample (average value)	Standard specification
Density (kg/m^3)	0.8723	0.86-0.90
API gravity	29.0	-
Pour Point (°C)	8	18 max
Flash Point (°C)	168	130 min

A comparison was made between biodiesel from used cooking oil and conventiona diesel showed that there were some differences in physical properties. However it still me the requirement of diesel fuel specification.

The difference in some of the physical properties such as pour point, flash point an density was due to the fact that biodiesel from used cooking oil was very much different i chemical composition to conventional diesel. The calorific value or gross heat of combust of biodiesel from used cooking oil was lower than conventional diesel, because of the high density for biodiesel from used cooking oil compared to conventional diesel fuel. Th different of these properties have directly related or influence to the engine characteristic and give an advantage to the engine performances, however up to certain extend.

The properties and characteristic of blended biodiesel was slightly different to th properties and characteristic of conventional diesel fuel, as shown in Table 3. Therefore; it i technically suitable to be used as an alternative fuels for diesel engines. However, not a properties and characteristics gives the better results compare to conventional diesel but it' still met the requirements of diesel fuel specification.

As seen in Table 3, the flash point for biodiesel from used cooking oil is 168 °C, we above conventional diesel fuel's flash point of 74 °C. Testing has shown the flash point c biodiesel blends increases as the percentages of biodiesel from waste cooking oil increase Therefore, biodiesel and blended biodiesel from used cooking oil with conventional dies are safer to store, handle, and use than conventional diesel fuel.

Table 3 Properties of blended biodiesel

Sample	Diesel	B1	B2	B3	B4	B5
Density (kg/m^3)	0.8358	0.8363	0.8374	0.8378	0.83.80	0.8385
API gravity	36.4	36.1	36.0	35.9	35.8	35.7
Pour Point (°C)	-2	-2	-2	-1	-1	-1
Flash Point (°C)	74	75	75	76	76	76
Calorific value (kJ/kg)	44989	44969	44962	44954	44946	44936

From the results obtained, it can be seen that the blended biodiesel from used cookin oil can be used in diesel engine. Blended biodiesel with 5% volume of methyl ester fro used cooking oil give a better result than diesel fuel itself. Although it have som disadvantages such as the calorific value is lower than diesel, but its still within specificatio limits for engine performance

3.2 Performance Characteristics of Diesel Engine.

Speed, brake load and fuel consumption for each fuel samples was obtained to evaluate the behavior and performance of diesel engine. These experimental data were analyzed to determine brake power, brake mean effective pressure, specific fuel consumption and brake thermal efficiency.

The graph of brake power versus brake mean effective pressure is shown in Figure 4. From Figure 4, it can be seen that the brake power increased as a brake mean effective pressure increased. This shown that the brake mean effective pressure is proportional to brake power. It is because brake power produced by the engine was influenced by engine speed and brake load. It does also give the same effects when the brake load increased. When speed is increased, it will produce more power to the engine. Brake power at speed 2000 rpm gives the maximum value of 11.82 kW, which is twice than value of brake power at speed 1000 rpm, i.e. 5.91 kW.

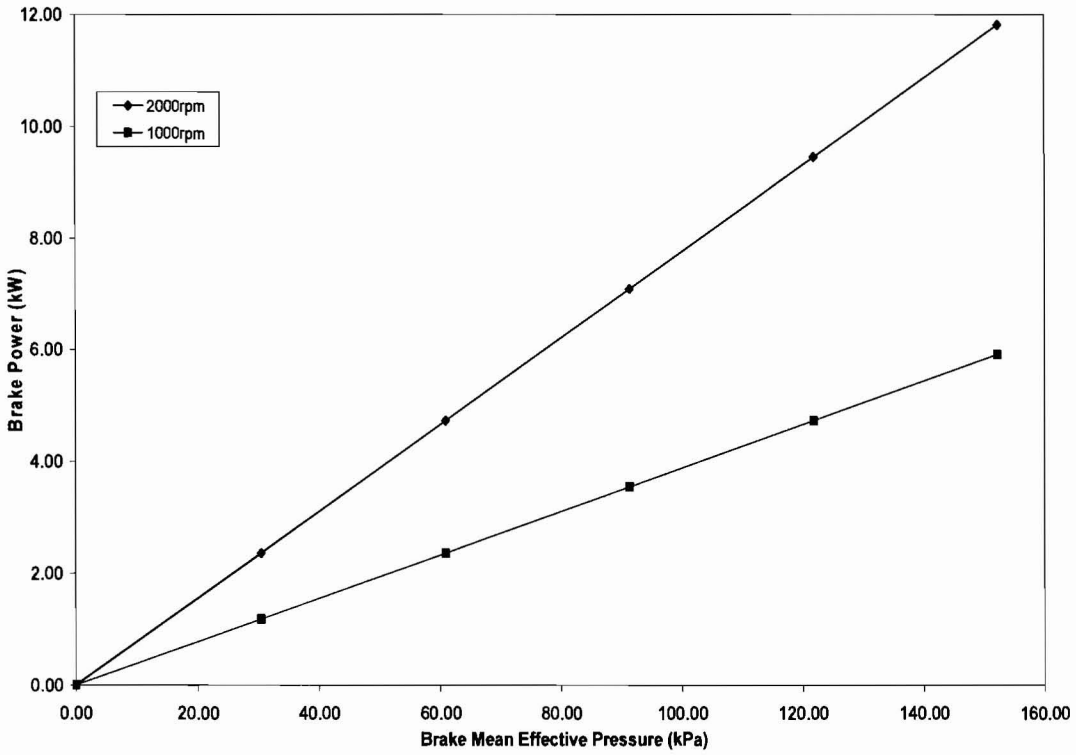

Figure 4 Brake power versus brake mean effective pressure

Figure 5 shown that all blended fuel samples produce almost the same specific fuel consumption as conventional diesel fuel for each speed. Specific fuel consumption decreased when brake mean effective pressure increased. The same trend curve was produced for both engine speeds. It also shown that engine at 2000 rpm speed consumed more fuel than engine at 1000 rpm speed. So when the engine speed is increased, the specific fuel consumption will also increase.

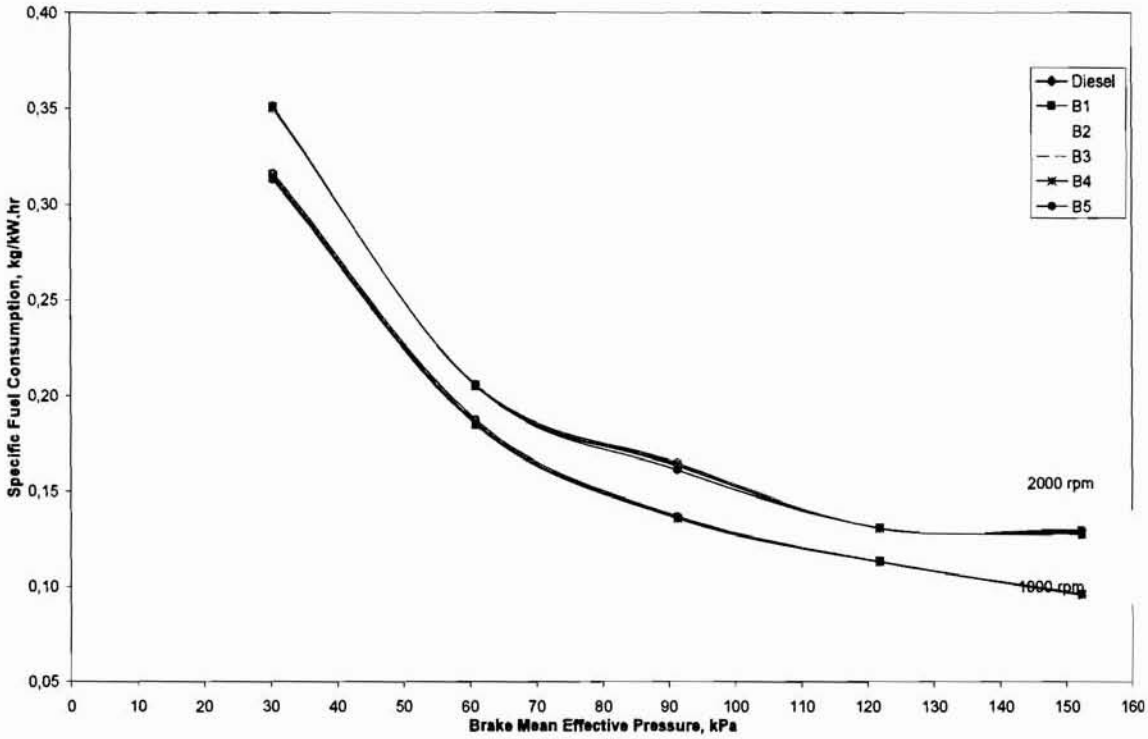

Figure 5 Specific fuel consumption versus brake mean effective pressure

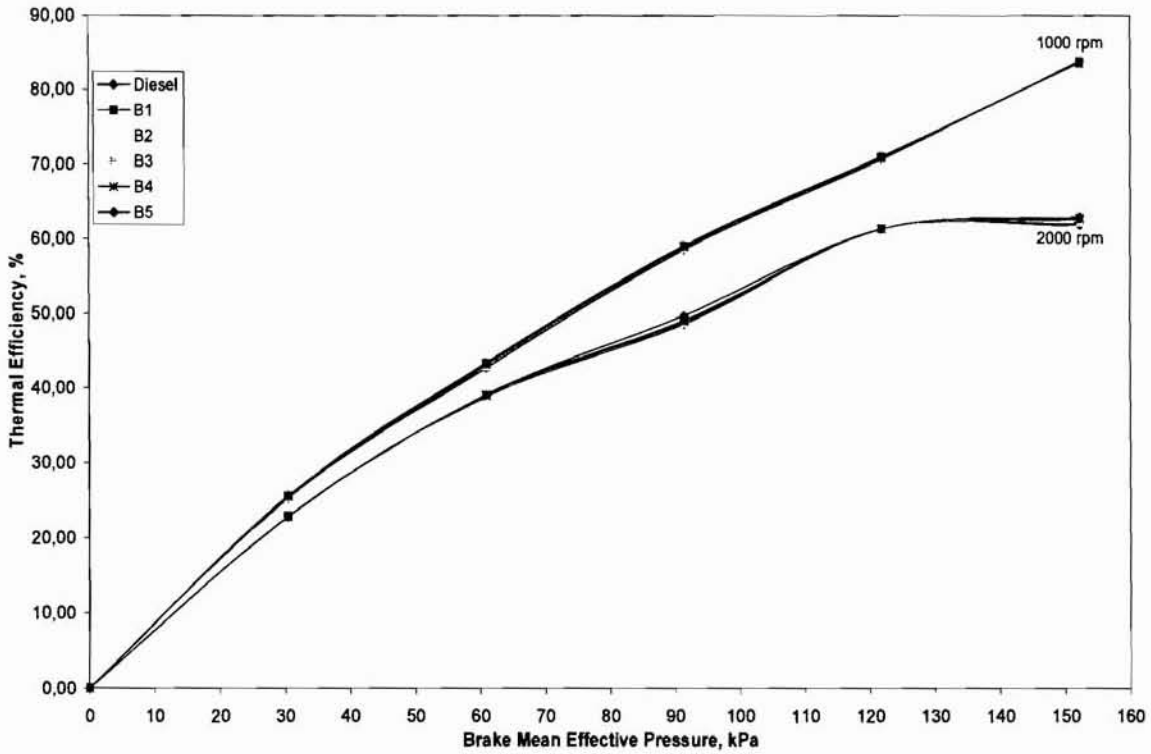

Figure 6: Thermal efficiency versus brake mean effective pressure

Figure 6 shows that all blended biodiesel produced the same performance in term of thermal efficiency as the conventional diesel fuel. Both graphs shown that when brake mean effective pressure increased the thermal efficiency will also increase until certain level. But when the engine speed increased, the value of thermal efficiency was decreased. Engine with speed 1000 rpm had the maximum thermal efficiency around 83.7 % but the engine with speed 2000 rpm had the maximum value around 62.9%.

From these results, it clearly seen that blended biodiesel from used cooking oil can be used as fuel for diesel engines up to 5% volume of blended biodiesel from used cooking oil and produces almost the same characteristic of engine performances as compared to the conventional diesel fuel.

4.0 CONCLUSION

1. The used cooking oil can be converted to the biodiesel through simple transesterification process.

2. The evaluation of fuel properties and characteristics of biodiesel derived from used cooking oil showed that it technically suitable for use in diesel engine. Generally, their properties and characteristics were largely within standard specification of biodiesel.

3. The increases in flash point as the percentages of biodiesel from used cooking oil increases also shown that produced biodiesel blended fuel are safer to store, handle, and use than conventional diesel fuel. Although the calorific value of the blending samples was lower than conventional diesel, but it still met the requirement of diesel fuel specification. The difference in some physical properties such as specific gravity have directly influence to the engine performance characteristic.

4. Results from constant speed diesel engines test showed that the blending fuel samples produced almost the same performance characteristics as compared to the conventional diesel. Therefore, blended biodiesel from used cooking oil is suitable to be used up to 5% as a fuel for diesel engine at constant speed and gives the same engine performances as conventional diesel fuel.

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